§26. Development of ECH Method for High Density Plasma Heating

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Recently, there arises considerable interest in ECH methods for heating and current drive of high density plasmas, where the central density is higher than the plasma cutoff density for the injected RF frequency. In this case, the propagation mode in the central plasma must be electron Bernstein (B) waves, since usual O and X modes can not propagate in overdense plasmas. Although B waves have no density limit for propagation and have potential ability to heat high density plasmas, they have to be excited in plasmas via mode conversion process from the electromagnetic waves injected from outside. The O-X-B method is a possible way to excite B waves in the plasma 1). Here we present the results of numerical investigation on this method for ECH in LHD and initial experimental results on LATE.

Typical ray trajectory is shown in Fig.1. The parameters used for calculation are frequency (84 GHz), the central magnetic field (2.6 T), electron density (1.4x10^20 m^-3), and temperature (500eV). Obliquely injected O waves at appropriated angle to the magnetic field are mode-converted to X waves at the plasma cutoff layer, and the X waves then propagate back toward the upper hybrid resonance (UHR) layer and are mode converted to B waves, which propagate again toward the high density plasma core. The refractive index parallel to the field line is given by N//=(NpBp +NtBt)/B=Np(Bp/Bt)+Nt, where Np and Nt are poloidal and toroidal refractive indices, respectively. Since B wave is an electrostatic mode and has a large refractive index N, the poloidal contribution Np(Bp/Bt) becomes large and B waves are damped away via Doppler shifted cyclotron resonance before arriving at the ECR layer (B=3 T for f=84 GHz). The deposition profile is quite narrow (Δ r/a=5%) and its location is insensitive to electron temperature, which is ascribed to the dispersion character of B waves 1). Since the width of injection angle of O waves, in which conversion efficiency from O to X waves is high, is narrow for present LHD plasma, a well focused and accurately directed beam is required. Numerical investigations show that high conversion efficiency can be obtained by using present horizontal injection antenna.

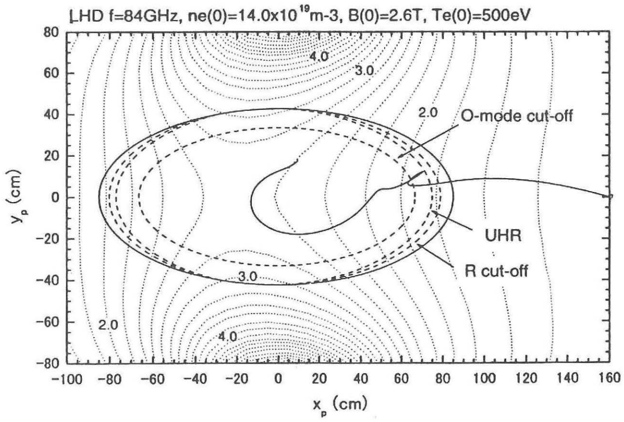

Fig.1 O-X-B ray trajectory in an LHD plasma

A new experimental device, LATE (Low aspect ratio Torus Experiment) has been constructed to investigate the basic physical mechanism of plasma production, heating and current drive by RF power at electron cyclotron frequency without Ohmic heating power in low aspect ratio torus plasmas. For initial experiments we injected RF power (2.45 GHz, 5 kW) in the form of O waves obliquely to the toroidal field as shown in Fig.2. The plasma current up to 3 kA is generated and maintained during RF injection (~ 1sec). The line averaged density is beyond 1.0x10^17 m^-3, which is higher than the cutoff density in the present case (0.7x10^17 m^-3). This result suggests that the B wave heating takes place in the overdense plasma core.

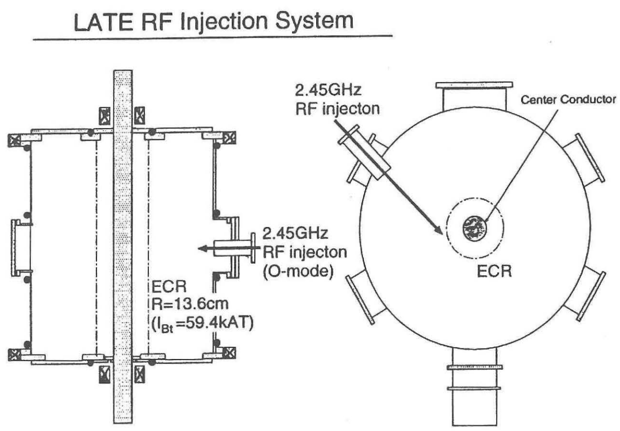

Fig.2 RF injection system for the LATE device

References

1) Maekawa, T.et al., J. Phys. Soc. Jpn. **48**, (1980) 247.